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14. ABSTRACT
This research effort measured the spectral and temporal dynamics of human auditory attentional control, concentrating on the requirements for efficient shifting of auditory attention within the frequency spectrum of normal human hearing.

15. SUBJECT TERMS

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FINAL REPORT

Abstract:
Auditory thresholds of normal listeners for detecting pure tones in noise depend on attention. First, cuing a frequency in advance benefits detection. The benefit is larger, and appears more rapidly, at low than high frequencies, as if the time-course of attentional focusing is frequency-dependent (Scharf, Reeves, & Suciu, *JASA*, 2007.) Second, compared to uncertainty, frequency certainty increases overshoot with broadband noise but decreases it with narrowband noise, possibly due to attentional focusing (Scharf, Reeves, & Giovanetti, JASA, 2008). Third, the broadening and downward peak shift of the attention band with decreased tone duration can be modeled by probability summation (Reeves, 2008). Fourth, we have discovered an unexpected interference of valid cues on detection of up-coming signals which, unlike forward masking, is the same for ipsi- and contra-lateral stimulation and is seen at low signal intensities (paper in preparation for *JASA*).

Objectives: *Attention Shifting*: no change from the original proposal. We also studied the widening of the *attention band* for brief tones and the role of attention in *overshoot*. These experiments were not originally proposed in the grant but were consistent with our goal of better understanding the role of attention in auditory detection.

Accomplishments

Attention Shifting: We have completed all ten experiments proposed in the grant. Typically, 40 ms pure tone signals were presented on a 300 - 6000 Hz white noise background; the signals in Experiments 2-10 were preceded by cues of the same duration and the same or different frequency. Experiment 1 confirmed that with no cue, when compared to frequency uncertainty (frequency randomized over trials), frequency certainty (same frequency on every trial) aids detection more at low than at high frequencies. Experiment 2 showed that detection thresholds improve after an uncertain frequency has been validly cued, asymptoting to the level of frequency certainty within 300 msec. Thresholds improved rapidly at low, but not high, frequencies, and then progressed towards asymptote at the same slow rate at all frequencies. We suggested that the time needed to focus attention on a cue frequency followed the same frequency-dependent time-course as did the thresholds (Scharf, Reeves, & Suciu, JASA, 2007.) However, in Experiments 3 and 9, we attempted to measure the time course of an attention shift from one cued frequency to another, and found that this was equally fast at all frequencies. So why then did attention appear to focus slowly in Experiment 2 ? An alternative hypothesis, mentioned briefly in the JASA 2007 paper, was that attention focuses rapidly at all frequencies, but that the cue, though valid, exerts a frequency-dependent interference on signal detection. In Experiments 4-8 and 10 we studied what we now call 'forward interference' in detail. The effect reaches 5 dB in magnitude; it is greater for frequency-valid than for frequency-invalid cues (distractors); it does not depend on cue level for cues from 4 dB to 12 dB above threshold; and it is the same for ipsilateral and contralateral cues. This pattern of results shows that forward interference is not forward masking; instead, it appears to be a novel effect. Subtracting our interpolated estimates of forward interference from the threshold elevations found in Experiment 2, on the (as yet unproven) assumption that focusing and interference reflect two separate processes, it appears that attention may indeed focus rapidly at all frequencies.

We also confirmed that the *attention band* widens as tone duration decreases (Wright & Dai, 1994) from (in our case) 300 ms to 40ms or 20 ms. We used a probe-signal method in which 8 probes tones, each 1/16th probable, were disposed in frequency symmetrically around the 50% probable 1000 Hz signal. Results at the center of the attention band were interesting. For listeners who focused more narrowly, detection of the brief (20 and 40ms) tones was slightly worse for both 925 and 1075 Hz probes than for the 1000 Hz signal, but for listeners who focused broadly, detection was *better* for the 925 Hz probe than for the 1000 Hz signal, though still worse for the 1075 Hz probe. This surprising asymmetry in detection can be modeled by probability summation across a bank of individually-asymmetric auditory ROEX filters which resemble critical bands, even though the filters are placed symmetrically in log frequency on either side of the signal to model the assumed disposition of attention (Reeves, 2008). Paying attention to fewer filters necessarily narrows the attention band and reduces the asymmetry; as it takes time to focus, only with long-duration (300 ms) tones is the attention band optimally narrow for every listener.

We also established a role for attention in *overshoot* (Scharf, Reeves, & Giovanetti, 2008), although many other factors contribute to this effect. Overshoot was measured with signal frequency certain (same frequency on every trial) or uncertain (randomized over trials). In broadband noise, thresholds were higher 2 ms after masker onset than 200 ms later, by 9 dB with frequency certainty, and by 6 to 7 dB with uncertainty. In narrowband noise centered on the signal frequency, thresholds at 2 ms were not elevated with certainty, but were elevated 4 to 5 dB with uncertainty. Thus, frequency uncertainty leads to *less* overshoot in broadband noise, but to *more* overshoot in narrowband noise. Reduced overshoot in broadband noise may come about because the masker, given its many frequencies, disrupts focusing at onset as much under certainty as uncertainty. Once the initial disruption dissipates, threshold is lower with certainty so overshoot is greater. In contrast, a narrowband noise with frequencies only near the signal does not disrupt focusing when the signal frequency is known beforehand, so overshoot is absent. When frequency is uncertain, the narrowband noise serves to focus attention on the signal frequency; since this requires time, detection near noise onset is poorer than later on, so overshoot is present.

<u>Personnel Supported</u>. Our programmer, Zhenlan Yin, started work on the grant in July 2004, and has remained with us as a PhD student in our program (which fully supports her). Our first technician, John Suciu, is now in graduate school. We replaced him with

Jennifer Olejarczyk, who is now a research technician at MIT, during 2007. Holly Giovanetti was an phenomenal undergraduate research assistant, not supported by the grant. Scharf worked on the grant for 3 months of each year; Reeves worked half-time on the grant.

<u>Publications</u>:

Scharf, B., Reeves, A., & Suciu, J. (2007). The time required to focus on a cued signal frequency. *Journal of the Acoustical Society of America*, 121, 2149-2157.

Scharf, B., Reeves, A., Giovanetti, H. (2008). The Role of Attention in Overshoot: Frequency Certainty vs. Uncertainty. *Journal of the Acoustical Society of America*, *123*, *1555-156.*

Reeves, A. (2008). The Auditory Attention Band asymmetry at short durations: data and model. Book Chapter to be submitted to a Festchrift for George Sperling.

Scharf, B., & Reeves, A., (2008). Reduced signal detection following a weak tone burst. To be submitted to the *Journal of the Acoustical Society of America*.

Interactions.

Results have been presented at three meetings:

Reeves, A. , Scharf, B., Suciu, J., and Ji, Z. (2005). Focusing Auditory Attention From Broadband To Single Tones: Faster At Lower Frequencies. Psychonomic Society, Toronto, November.

Reeves, A. (2007). Attending to pure tones. Invited speaker. Festschrift for George Sperling, UCAL Irvine, July.

Reeves, A. (2007). Cuing effects. Psychonomic Society, Long Beach CA, November.

Other laboratories. There is an on-going interaction in auditory psychophysics with Prof. Mary Florentine at Northeastern.

Technology transfer: none.